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Use of an HF active monitoring array in the presence of high level interference

K.L. Beeke, M.A., C.Eng., M.I.E.E.

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

USE OF AN HF ACTIVE MONITORING ARRAY IN THE PRESENCE OF HIGH LEVEL INTERFERENCE

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Summary

An electronically-steerable, active receiving array for HF was developed at BBC Research Department a few years ago. An investigation has now been carried out to find the limiting operating conditions for the array, i.e. under what maximum levels of interference it can be operated satisfactorily.

Typically, it has been found that if interference levels are greater than about 100 dBµV/m, then some form of screening will be required, especially if the wanted signal level is very low and on a frequency close to an intermodulation product of the interfering signals.

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M.E.B. Moffat

Head of Research Department

Research Department, Engineering Division,
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1. INTRODUCTION

An electronically-steerable active receiving antenna array for HF was developed by BBC Research Department. This array is described in detail in Ref. 1. The salient features are given below.

Array	Linear
Frequency range	6 - 26 MHz
No. of elements	8
Type	2 m vertical whip (active)
Effective element height	1 m at 6 MHz
Minimum field strength	1 μV/m
Combiner	Summation via 8-bit binary switched delay-lines
Pattern	Independent single null and/or main beam steering

This Report describes an investigation into the performance of the array when operated in the presence of high level, local interference. This is of interest because the array may usefully be co-sited with HF transmitters, or near other high power transmitters: either as a monitoring array or as a reserve feed of programme in an HF rebroadcast arrangement.

2. FACTORS TO BE CONSIDERED

It was envisaged that the main problem would be that high level signals at the input to the element amplifiers[2] would give rise to unacceptable levels of intermodulation products (i.ps). These are a result of non-linear behaviour by the amplifiers.

There are three factors which should be considered:

(i) What are the wanted signal levels?

(ii) What are the likely levels of interference?

and (iii) What are the i.p. levels?

For use as a reserve feed, the levels of wanted signal are not likely to be as low as the 1 μV/m specified for the monitoring requirement in the introduction. Typical figures predicted at various sites around the world fed from the UK are of the order of 40 dBμV/m. Of course propagation conditions, etc., will ensure that a range of received signal levels will be found at any site.

It should be noted that high levels of interference are only a problem if the wanted signal level is low. If the wanted signal level is high, then the problem may be resolved simply by attenuating the signal at the input to the amplifier. This can be achieved by using a shorter antenna. The levels of interference can be reduced in some instances by screening the receiving antennas from the interfering source(s).

3. EXPERIMENTAL WORK

The first measurements to be made were field strength measurements. These were carried out in the vicinity of a transmitting station — one of the most likely sources of high level interference.

The measurements were taken using a whip antenna feeding a field strength meter. The whip was a 2 m monopole, mounted on a ground plane. It was the same as the array elements except that the base amplifier could be bypassed, i.e. the whip could be used as either a passive or an active antenna. For the field strength measurements the whip was used in its passive mode.

In addition, a qualitative analysis of the element amplifier was carried out. The signal from the whip was fed into a spectrum analyser and high level signals could be identified using the element in its passive mode. Operating the element as an active whip enabled the i.ps to be seen. This is illustrated in Fig. 1.

Further investigations into the amplifier performance were carried out and measurements were made. A remote HF broadcast was found and its frequency noted. Two high level signals were coupled into the amplifier, together with the remote signal. The frequencies were chosen so that a third order i.p. would lie on the broadcast frequency. A receiver, fed by the amplifier output, was then tuned to the remote signal frequency. In this way, it was possible to determine the levels at which the distortion became unacceptable.

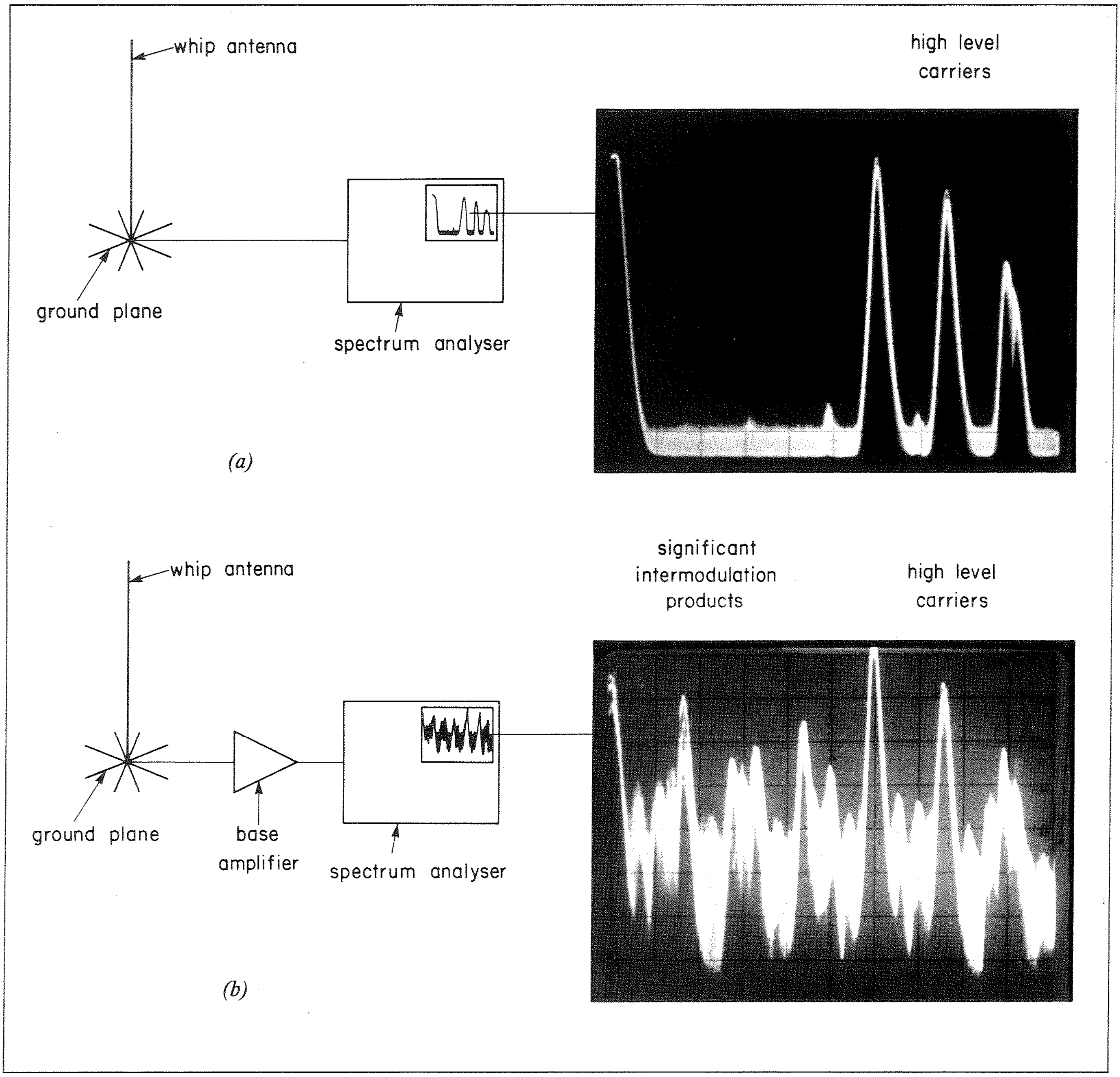

Fig. 1 - Intermodulation products generated in the presence of high level signals.
a) Passive receiving antenna, carriers only. b) Active receiving antenna, significant i.ps have been generated.

4. RESULTS

At distances in the range of 100 - 300 m from the transmitting arrays (radiating 250 kW), the field strengths were in the range of 1 - 10 V/m. Previous measurements indicate that the field strengths will fall, further from the arrays, to values typically 20 mV/m at 5 km. Closer to the arrays, the field strengths rise to about 50 V/m or more at 10 m.

Fig. 1 shows the significant level of i.ps which were produced when the element was operated in its active mode. At the measurement point, the highest carrier level (at 11.85 MHz) produced a field strength of 12.5 V/m. From Fig. 1(a) it can be seen that the other two carriers were approximately 7 dB and 21 dB below this. From Fig. 1(b), the highest i.p. produced by using the whip in its active mode is only about 3 dB below the second highest carrier level and is about 12 dB higher than the lowest level carrier.

From the laboratory measurements, three significant levels emerged. Note that these all correspond to a wanted signal of 40 dBμV/m with various high level interferers received with a 2 m whip.

i) 100 dBμV/m is the maximum tolerable interference level if immunity from i.ps is required.

ii) At interference levels of the order of 120 dBμV/m, the wanted signal should be offset from the i.p. frequencies by at least 10 kHz if it is to be received satisfactorily.

iii) If the interference level is greater than 140 dBμV/m then the present system is unusable.

5. DISCUSSION

We can now consider the information gained.

The points to decide are:

(i) What are suitable amplifier input levels?

(ii) What ratio of interfering signal strength to wanted signal strength can be tolerated?

Note that the above points are not independent. Very high amplifier input levels will give rise to high levels of intermodulation products. These are undesirable. There are various ways of reducing the input levels:

(i) Introducing some form of screen to reject local interfering signals.

(ii) Shortening the whip.

Shortening the whip will reduce the wanted signal as well as the interfering signal. However for each 1 dB attenuation, the relative i.p. level will be reduced by 2 dB.

The minimum length of the whip is limited by the amplifier's noise floor.

The figures in Section 4 indicate the order of interference levels which can be tolerated for a typical wanted signal level of 40 dBμV/m. It is instructive however, to analyse the requirements for other signal levels.

The Appendix shows that when the i.p. falls on the frequency of a wanted signal, then the condition for satisfactory reception is given by

$$s \geqslant x - \frac{1}{3}(y + 2a + 260) \text{ dB}$$

where x is the local interference level,
y is the wanted signal level,
a is the attenuation introduced by shortening the whip,
and s is the amount of screening required.

Fig. 2 shows the level of screening required as a function of the level of wanted signal and the levels of the local interfering signals. In the ideal circumstances, no screening would be required of course. At high power HF sites it is most likely that some form of screening would be needed.

At some sites it might be possible to make use of the local terrain to provide some degree of screening. For instance, if the receiving array could be situated in an area where the ground level falls away from the interfering transmitting arrays, then the necessary screening might be reduced. However, it would be necessary to make measurements at the site in question if advantage is to be taken of the local terrain.

If the wanted signal frequency were offset from the frequency of a significant i.p. by more than 10 kHz, then an increase in interference level of 20 dB can be tolerated.

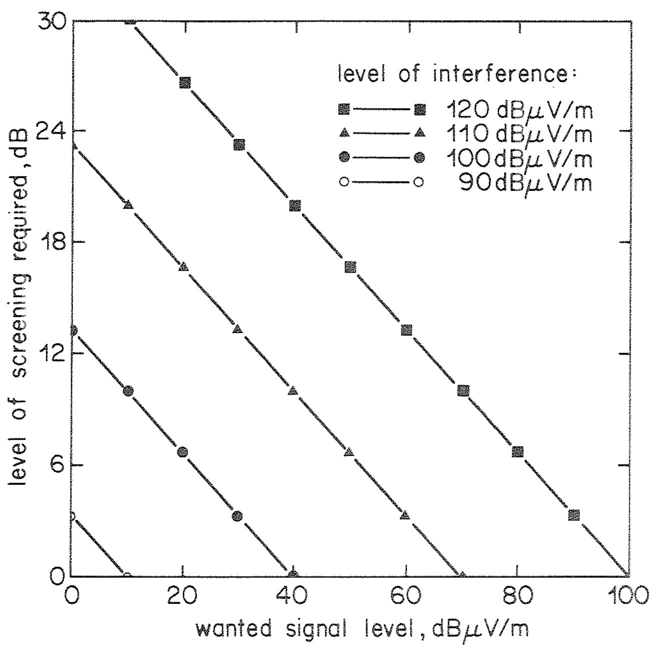

Fig. 2 - Variation of minimum required screening with wanted signal level and local interference level.

6. CONCLUSIONS AND RECOMMENDATIONS

An investigation has been carried out into the possibility of using an existing active HF monitoring array in the presence of high level interference.

The following conclusions refer to a particular design of antenna base amplifier given in Ref. 2. The results for another design of amplifier might well be significantly different.

For interference levels greater than 100 dBμV/m the effect of system non-linearity becomes significant. The first noticeable impairment to reception is at or near the frequencies of the major intermodulation products. The system is not usable if interference levels are greater than 140 dBμV/m.

If the interference level is greater than 100 dBμV/m, it will be generally necessary to reduce the level by screening the array. Alternatively, the effects of the system non-linearity could be reduced.

This may be achieved in two ways. The first would be to improve the linearity of the base amplifier and, if it proved to be necessary, the following receiver. The second would be to reduce the input signal level by shortening the whip. However, improvements gained by shortening the whip will be limited by the noise floor of the amplifier.

If the wanted signal lies at least 10 kHz from an i.p. frequency, the degree of screening required will be reduced by about 20 dB. Further reductions may be acceptable if advantage is taken of the local terrain and a position found where the interference is minimised.

It is recommended that an HF field-strength survey should be made at any site where the use of a monitoring array is proposed.

7. REFERENCES

1. ROBINSON, A.P. 1985. An electronically-steerable active receiving array for HF. BBC Research Department Report. No. BBC RD 1985/2.

2. PRICE, H.M., and LYNER, A.G. 1977. An active aerial element for HF/MF receiving arrays. BBC Research Department Report No. BBC RD 1977/36.

APPENDIX

Signal Levels Required for Satisfactory Operation of the Active Array

There are several variables involved when analysing the requirements for satisfactory operation of the active array. This Appendix shows the relationship between them and derives an expression for the shielding which would be required under certain conditions.

The required levels can be predicted as follows:

Let the local, interfering, transmissions have a level x dBμV/m

Let the wanted signal have a level y dBμV/m

Let there be some form of screening which attenuates the local interference by s dB.

Then the effective local interference

$$x_e = x - s \text{ dB} \tag{1}$$

Let the attenuation introduced by shortening the whip be a dB.

Then the local interference level at the input to the amplifier:

$$x_i = x_e - a \tag{2}$$

and the wanted signal level at the input to the amplifier

$$y_i = y - a \tag{3}$$

Let the i.p. levels produced by input at level k be;

$$k - d(k) \text{ dB}$$

Let the difference in wanted signal and i.p. level for satisfactory reception be Δ dB

Thus, if the wanted signal lies on an i.p. frequency we require;

$$y_i \geqslant x_i - d(x_i) + \Delta \tag{4}$$

Consider the requirements for a wanted signal level of 35 dBμV/m (note that with a 2 m whip, this corresponds to 35 dBμV). At a wanted signal level of 40 dBμV at the input to the amplifier the interfering signal levels had to be no greater than 100 dBμV at the input to the amplifier if the wanted signal were to lie on an i.p. frequency.

Substituting $y_i = 40$, $x_i = 100$ in (4) gives

$$40 = 100 - d(100) + \Delta$$

i.e.,

$$d(100) - \Delta = 60 \text{ dB} \tag{5}$$

Now, at other values of x_i,

$$d(x_i) = d(100) + 2(100 - x_i) \tag{6}$$

Substituting (6) in (4) gives;

$$y_i \geqslant x_i - [d(100) + 2(100 - x_i)] + \Delta \tag{7}$$

Substituting (5) in (7) gives;

$$3s \geqslant 3x - y - 2a - 260 \tag{8}$$

Considering the wanted signal $y = 35$ dBμV/m: suppose the interfering signal level $x = 137$ dBμV/m.

Substituting these numerical values into (8)

gives:

$$s \geqslant \left(39 - \frac{2a}{3}\right) \text{dB}$$

e.g. if

$$a = 6$$

$$s \geqslant 35 \text{ dB}$$

Thus, in the example, the amount of screening of the interference signal required is a minimum of 35 dB.